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ETF MINING TRUCKS

Mining haulage for the 21st century

Technical Presentation

ETF Trucks & Maintenance System

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Content:

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- General Concept
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- Monorail Frame
- Oscillating Axles
- Suspension System
- All-Wheel Steering
- Braking Systems
- Weight Distribution
- Tires
- Lighting
- Cabin
- Dumper
- Hydraulics
- Electronics
- Filtering
- Automatic Coolers Purging
- Vibration Reduction Chips
- Dirt Protection & Cleaning
- Safety Features
- Environmental Impacts
- Life Cycle M & R system
- Truck Repair Monitoring System
- Workshop & Team
- MT-240 dimensions

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General Concept:

ETF Trucks are designed to overcome the shortcomings of existing large haul trucks with regards to:

- **More Mine Production**
- **Increased Mechanical Availability**
- **Specific Operational & Climatic usage**
- **Safety**
- **Environmental care**
- **Operator care**

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ETF Truck Range

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Trucks

MT-170

Payload
170 US tons (155 MT)

MT-240

Payload
240 US tons (218 MT)

SLMT-240

Payload
240 US tons (218 MT)

Configuration:

MT-170	16x16x16
MT-240	20x16x20
SLMT-240	20x16x20

Haul Train

4x HT-218 One operator!

Payload 873 US tons (794 metric tons)

Configuration:

HT-218	20x16x20

Self Loading Haul Train

4x SLHT-218 One operator!

Payload 873 US tons (794 metric tons)

Configuration:

SLHT-218	20x16x20

Haul Trains available in 2,3,4,5 or 6 units each

Configuration:
Total no. of axles x no. of driven axles x no. of steering axles

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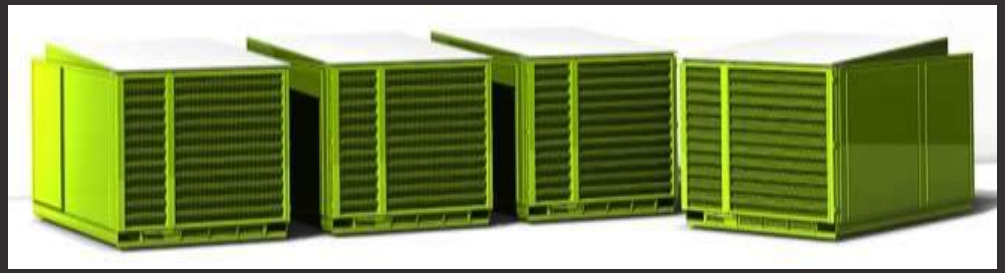
Power Pack Units



Four engines per truck offer three times Redundancy for Backup Steering and Braking systems.

(In case of an engine failure, it will 'automatically' shut down with no involvement by the operator while the truck remains fully operational.)

MTU / Mercedes V8 turbo-charged, 15,9 liter displacement
Rated Power 480 kW , Max Power 576 kW @ 1,800 rpm
Rated Torque 2,800 Nm, Max. Torque 3,360 Nm @ 1,300 rpm
Engine Brake Power, 345 kW @ 2,300 rpm
EPA Tier 3 - EURO Stage III
Water heating system optional

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Propulsion system

HYDRO-KINETIC DRIVE & RETARDING

Closed-loop Hydraulic system propels Hydraulic Motors which powers the Wheel-Drive unit.

Wheel-Drive unit, reduction ratio 20:1

Each Power Pack Unit propels one axle line (4 wheels)

Hydraulic- & Wheel-Drive oil is cooled and filtered to 0.5 micron
All functions are electronically monitored

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Monorail Frame

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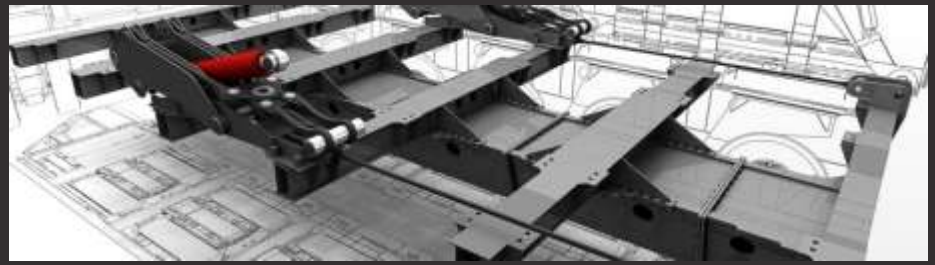

The main frame of an existing large haul truck is often the component that determines the lifetime of the vehicle. Large forces are transferred to the frame due to road impacts and shocks during loading.

ETF developed an innovative solution: the Monorail frame. Instead of a frame on top of the axles as in competitive vehicles, the ETF frame is between the axles. This results is a low center of gravity .

Existing vehicles have four points on which the load is transferred to the wheels. ETF's monorail and axle system has ten points on which the load is transferred to the wheels.

In this way, the forces to the frame are better equalized while eliminating frame torsion!

The monorail frame in combination with the long suspension travel reduces frame fatigue, resulting in extended life.

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Oscillating axles

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- Ten independent axles, 10 degrees oscillating Left & Right
- Effective cylinder stroke 950 mm (All axles)
- 20 wheels; 16 driven; 20 steering (20x16x20)
- Equal tire loading, optimal traction, increased stability
- Prevents vehicle swaying, reduces spillage
- Practically eliminating frame torsion

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Hydro-Pneumatic Suspension System

600 mm wheel travel out | Normal driving height | 350 mm wheel travel in

Current large haul trucks have a limited suspension travel resulting in extreme forces on the main frame.

ETF developed a special hydro-pneumatic suspension system which compensates the vehicle weight between individual axle-lines. The extremely long suspension travel of 950 mm protects the main frame from road and loading impacts. Another feature of the suspension is improved stability when negotiating curves resulting in higher permissible speeds and shorter trip times.

The wheels always stay in contact with the road surface for optimal traction.

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Hydro Pneumatic Suspension System

MT-240

The two front ETF axles support the same load as the single front axle from a conventional Large Haul Truck. Road impacts are thus 1/2. Due to the hydraulic compensation of the ETF front tandem this is again divided by 2:

Resulting in only 25% of the total road impacts compared with a conventional two axle truck.

The three rear ETF axles taking the same load as the single rear axle from a conventional Large Haul Truck. Road impacts are thus 1/3. Due to the hydraulic compensation of the ETF rear tridem this is again divided by 3:

Resulting in only 11% of the total road impacts compared with a conventional two axle truck.

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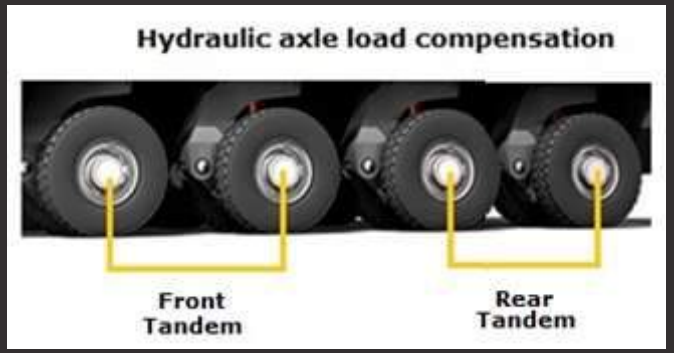
Hydro Pneatic Suspension System (2)

MT-170



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Hydro-Pneumatic Suspension System

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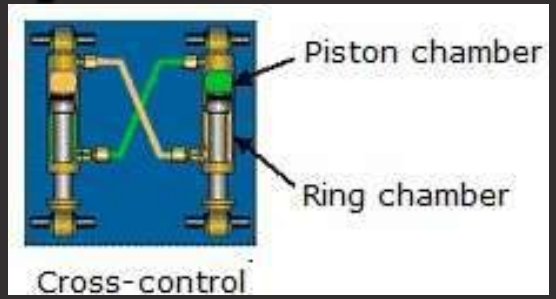
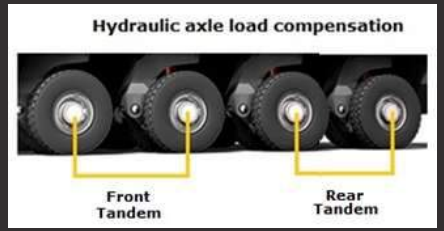


MT-240

MT-170



Front & Rear axles with Cross-Control of the Spring Cylinders

Advantages of CROSS-Control:

- Load balance between the two vehicle sides
- High roll-angle stabilization by controlling the spring cylinders:

  Piston chamber of one side to the Ring chamber of the other vehicle side
- Load balance between the vehicle axles, no shocks to the frame
- No overcharge of one axle at extreme spring movements

Resulting in:

- Much improved vehicle stability when negotiating curves
- Improved tipping stability
- Very comfortable suspension, no shocks reducing the ride comfort

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All-Wheel-Steering System

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ETF developed an unique steering system:

- All wheels are steered at low to medium speeds reducing tire wear, while at higher speeds the last two axle lines gradually change to rigid resulting in better stability.
- Automatic Speed-proportional steering system. At very low speeds, when spotting around the shovel, steering requires only two turns from lock to lock.
- All axles are equipped with two hydraulic steering cylinders, each with a separate hydraulic circuit. A 100% safety redundancy is build in as one cylinder is sufficient.
- In case of a fault in the steering, the axle is automatically lifted.

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Braking Systems

- **Full Dynamic Hydro-Kinetic Retarding on all powered wheels**
  - Retarding Torque 38,000 Nm per wheel
- **Dry disk, diameter 700 mm with 3 calipers on all wheels**
  - Braking Torque 59,055 Nm per wheel
  - Diagonal split brake circuits
- **Wet Parking Brake on all wheels**
  - Braking Torque 30,889 Nm per wheel
  - Capable of holding laden truck @ 15% incline
- **Anti-locking System (ABS) on all wheels**
  - Enables operation under slippery conditions with the steering capabilities in full function. The braking distance is also shortened considerably
- **In case of an emergency stop:**
  - Retarding & Dry disks are activated simultaneously

Braking system exceeds the requirements of SAE/ISO 3450

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Weight Distribution

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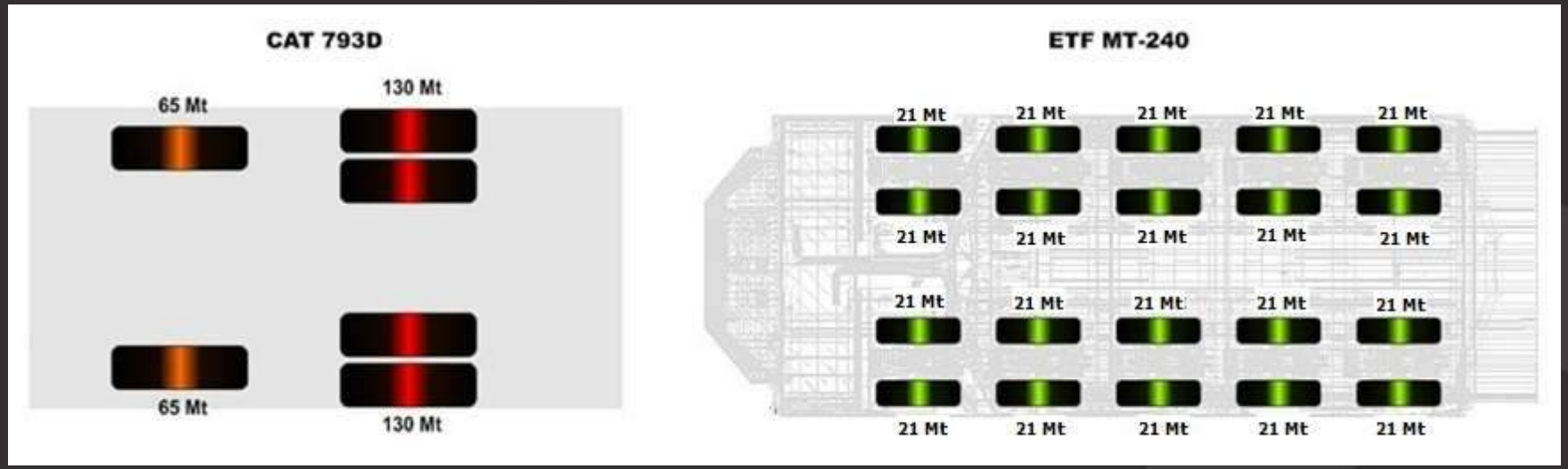

- **Total vehicle weight is equally spread over 20 wheels**

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Automatic Axle Lift

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On Empty haulage two axle lines (8 tires) are lifted to save tire costs.

In case of a Flat tire the axle is lifted to prevent total loss of the tire and damage to surrounding parts

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Tire costs addressed by:

- All-Wheel-Steering
- Oscillating axles and unique suspension
- Central tire inflation system
- Automatic axle lift
- Equal load spread over all wheels
- Automatic ‘on the fly’ wheel alignment
- Pressure and temperature sensors
- No vehicle swaying, Load spillage prevented

- ETF Tire size: 24.00R35
- Tires filled with nitrogen

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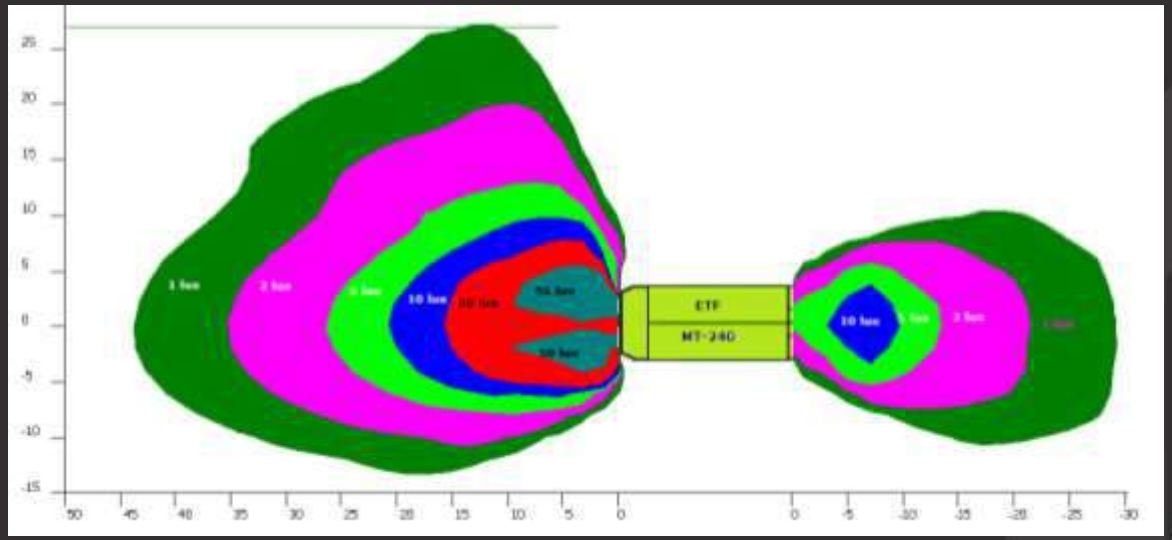
Enhanced vehicle lighting

- Xenon front lights, Cornering lights & Mirror lights
- LED Daytime Running Lights
- LED rear lights
- All lights & camera’s automatically cleaned (Front, Rear & Sides)



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Cabin (ROPS & FOPS)

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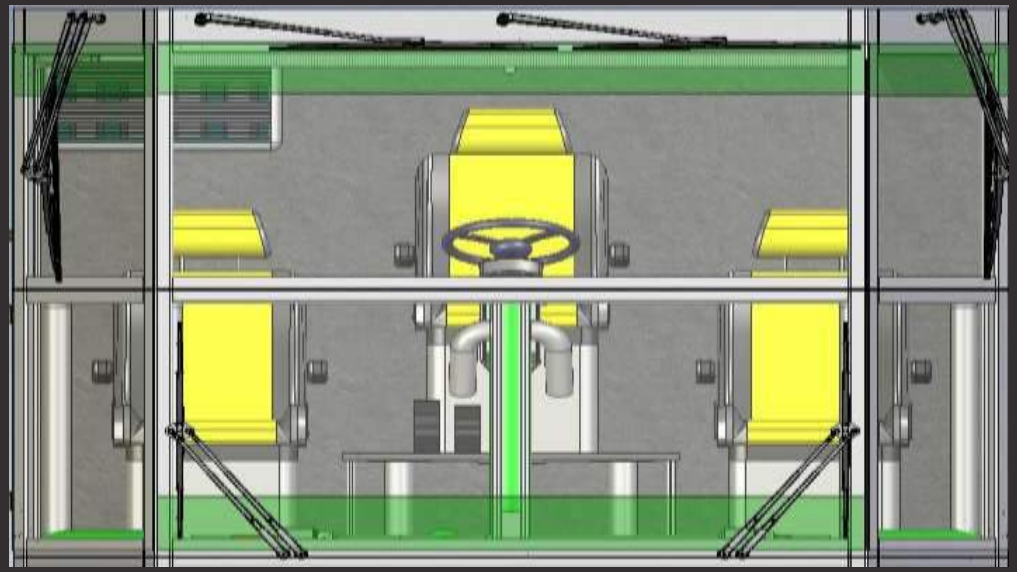

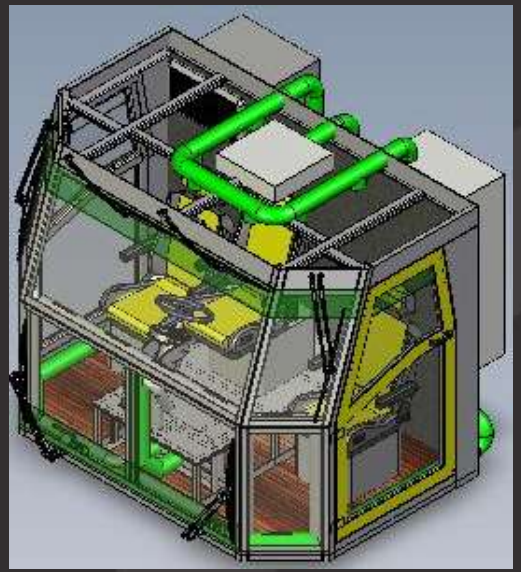

Three seat cab offers unrivalled visibility and unique operator training facility

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Cabin features

- Unique AC & Heating with filtered air intake
  - Diesel fueled parking heater
- Fully pressurized cabin
- Insulated glazing
- Left & Right entrance
- Safe operator training during production
  - Extra steering wheel & brake handle for trainer
  - Simulator not needed
- Heated & Ventilated seats
  - Operator, Trainer & Trainee
- Cabin shifts forwards to enter the machine room

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Dumper

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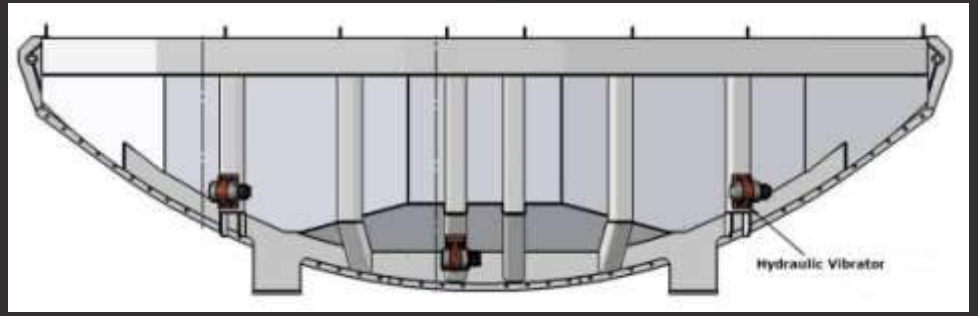

- Unique tipper mechanism which reduces stress on rear bearings and enables the use of single stroke cylinders.
- Polyurethane wear plates in front wall and rear door (no freezing)
- Hardox 450 wear plates in bottom
- Hydraulic vibrators (3) in front wall to prevent carry back
- Lifting cylinders: Single stroke, double acting (Stroke 2,460 mm)
- Dump angle: 50 degrees
- Dump cycle: 15 seconds (raise loaded) 15 seconds (power down)
- Time to change a Body: 60 minutes
- Heated body optional

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Dumper comparison

Dumping angle: 50 degrees
Body floor at 0 degrees

When a frozen load comes out in one piece during dumping it will have no negative effect on the stability of the vehicle

Dumping angle: 45 degrees
Body floor at – 11 degrees

Rear overhang in combination with the floor angle will operate as a pulling lever when the load comes out in one piece. In extreme cases this can cause the front wheels to lift off the ground!

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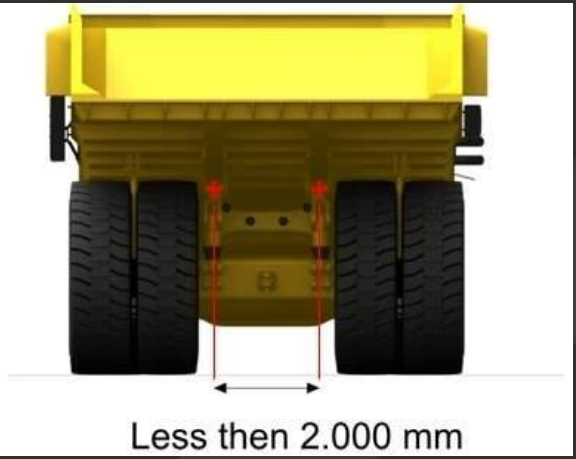
Dumper comparison (2)



Extreme dumping stability due to the large width of the dumper bearings

Limited dumping stability due to narrow width of the dumper bearings

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Hydraulics (Open Loop)

- **Three times redundancy for:**
  Braking, Steering, Tipping and Suspension
- **Pressurized Hydraulic tank**
  to avoid dust & moisture ingress
- **Designed for -50 to + 60 degrees Celsius operation**
- **All hydraulic functions electronically monitored**

Steering cylinders

Tipping cylinders

Spring cylinders

Suspension accumulators

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Electronics

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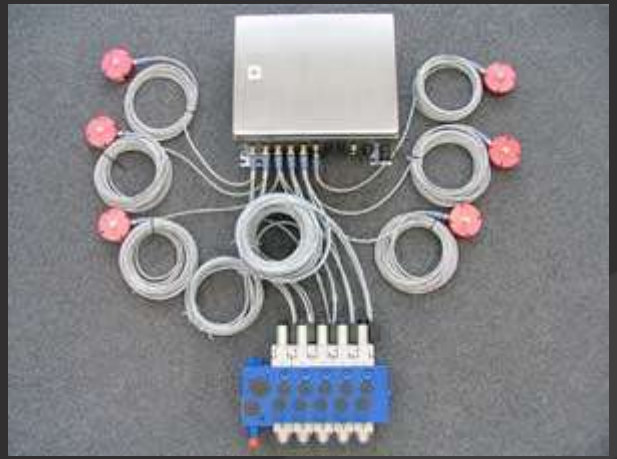

- Operational vehicle functions X-by-wire controlled using special embedded water proof controllers (IP67)
- Easy and fast maintenance & repair (Plug and Play)
- Detailed diagnose and fault finding process
- CAN-Bus communication
- Industrial made cabling with IP 67 connectors

Functions Safety because of system supervision

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Filtering

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- **Air inlet for Engine & AC:**
  Pre-cleaner and special filter elements
- **Fuel:**
  Pre-cleaner and 0.5 micron filter with water absorption
- **Engine oil & Pump drive box oil:**
  0.5 micron filters with water absorption
- **Closed-loop, Open-loop & Wheel drive oils:**
  Return filters and 0.5 micron filters with water absorption

Fuel Pre-cleaner

0.5 micron filter

All filters electronically monitored

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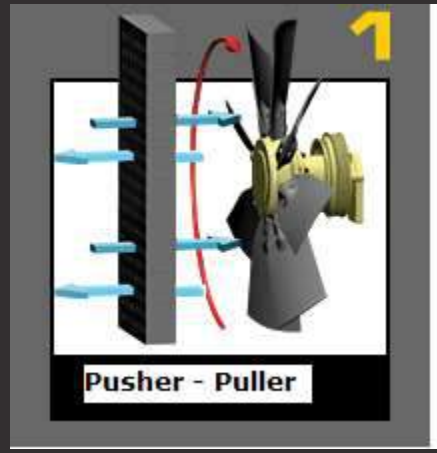
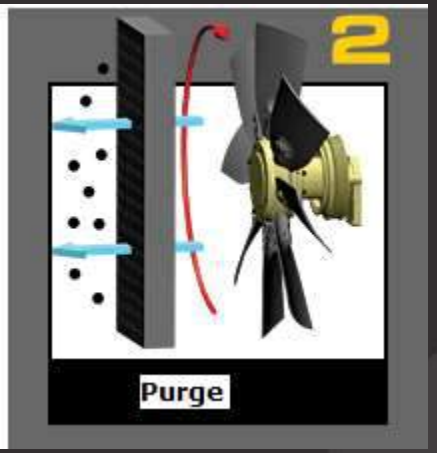
Automatic Coolers Purging





All cooling fans are reversed during tipping in order to remove any build-up of dust or flying debris

This function assures optimal cooling at all times, increasing mechanical availability

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Vibration Reduction Chips

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IMPROVEMENT OF COMBUSTION DUE TO FINER ATOMIZATION AND INCREASE OF THE CHARGE AIR FLOW SPEED

By applying VR Chips on high pressure injection lines or injection valves at a pump nozzle element (PDE) electromagnetic radiation is reduced. This causes the droplets of atomized fuel to decrease in size and increase in quantity. Individual fuel molecules receive more oxygen during the ignition process. This results in better combustion, which produces smoother and quieter engine performance.

The aerodynamic resistance in the long, twisted air-intake channels can be so great that it is negatively noticed in charging the combustion chamber. Turbo chargers used to improve the combustion charging also underlie the rules of aerodynamics. When using VR Chips on the barrier layers of the air intake system, the air speed in the peripheral zone is increased in order to create a more even airflow thereby reducing turbulences.

The VR Chips are applied on the injection lines, PDE and in certain areas of the air intake tract. With applying the VR Chips, the engine output is improved, the fuel consumption is reduced and the engine runs much smoother and quieter.

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Dirt protection & Cleaning

- All axles and frame are protected on top with composite covers *
- All cabling runs in conduit *
- All wheels are equipped with mudguards and rear mud flaps
- All axles equipped with front mud flaps
- At exchange of major components, only that specific area has to be cleaned which saves considerable downtime

* Capable of withstanding high-pressure cleaning

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Safety features

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- ## Unrivalled Visibility

  Aided by 4 cameras & Radar for Operator Assistance.

- ## Sleep Deterrent System

  The sleep deterrent system is monitoring the condition of the driver and tries to prevent him from falling asleep. The system works with the data source of the steering sensors. The steering sensors detect monotonous driving and steering characteristics typifying sleepy driving. The data generates, if needed, an audible warning to alert the driver and can even bring the truck to a complete standstill in an emergency case.

- ## Collision Warning System

  The collision warning system warns the driver for an approaching obstacle and acts actively to prevent a collision. The system is developed to warn a driver at dangerous circumstances before the situation gets out of control. Especially it is of assistance in cases of bad or limited view because of rain, dust, snow, fog etc. The system works with the data from the indurad Dual Range Radar.

- ## ABS & Traction Control

  Enables operation under slippery conditions with the steering capabilities in full function. The braking distance is also shortened considerably.

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Safety features (2)

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- ## Electronic Stability Control

  The electronic stability control is an integrated function of the hydro-pneumatic suspension. Current Large Haul Trucks have suspension struts which slide-in on one side and slide-out on the other side of the truck during cornering. The ETF suspension system slides in on one side but the sliding out on the other side is blocked during cornering. Herewith extreme stability is achieved. It also results in shorter trip times.

- ## Optical Safety System

  The optic safety system is also called "Anti blinding light". It prevents the driver from fatigue during trips at night. The system simulates a daylight situation for the eyes and brains and helps to prevent falling asleep. Another important feature of the optic safety system is the anti dazzle effect. Dazzling is next to fatigue as a leading cause of accidents at night or early morning.

- ## Enhanced vehicle lights

  Two cornering lights illuminate sharp curves for enhanced visibility and safety. At dark automatically two reversing mirror lights are activated. This provides the operator with illuminated view on the sides and back of the vehicle. This is just one of many unique ETF supplied safety features!

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Safety features (3)

- ## Factory fitted Fire Suppression System

  The best possible way to mount a fire suppression system is during the assembling of the truck. All connections, hoses and piping are mounted in such away that damage during operation will be avoided.
  All Power Pack Units are equipped with an individual Fire Suppression System.
  Insurance premium can be lower because the truck is delivered as standard fitted with this system.

- ## Head-up display The benefit of foresight.

  The standard feature in ETF Trucks, Head-Up Display presents the speed information directly in the driver's field of vision. The information is projected via the windscreen into the driver's field of vision, thus minimizing distraction.
  The driver's attention stays on the road ahead and the eye strain of repeated refocusing is eliminated.

- ## In case of an engine failure; Brake and Steering always remain powered

  With conventional trucks the brake and steering systems are no longer powered when the engine fails, relying on accumulator pressure only, which is not always sufficient. ETF trucks are equipped with four engines, in case of an engine failure the remaining engines power the brake, steering and suspension systems. (3 times redundant)

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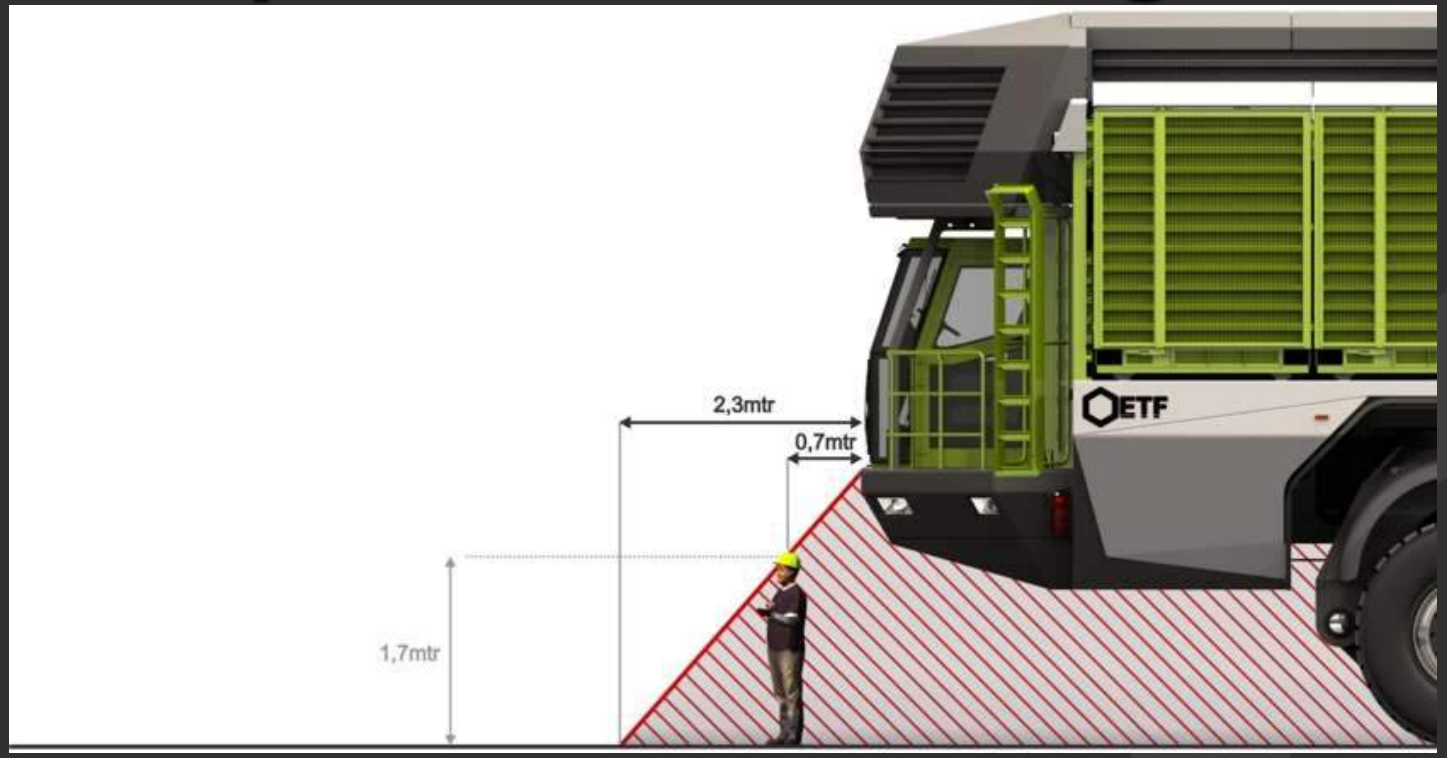
Operator's line of sight



Natural view within 1 meter from cabin (180 degrees)

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Operator's visibility

Unrivalled natural line of sight plus:

- 2 Mirror cameras
- 1 Forward camera
- 1 Reversing camera
- Dual Range Radar for Operator Assistance
  (Lane assist & approaching dump site)

Total visibility complies with ISO 5006

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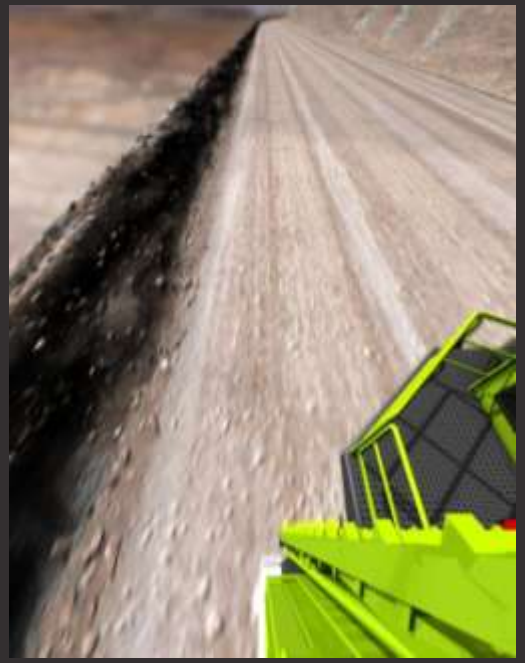
Camera view Front & Rear



Forward camera

Reverse camera

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View from mirror cameras

Left mirror camera

Right mirror camera

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indurad™ Dual Range Radar

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The indurad Dual Range Radar™ (iDRR) is a highly sophisticated and compact radar head for industrial applications. Contrary to industrial level gauge radar sensors the iDRR measures not only linear distances, but a two-dimensional surface profile. Besides this, it operates with 77GHz in a nearly three times a higher frequency range than level radar systems; The higher frequency enables detecting smaller objects at steeper angles.

The indurad iDRR supplies a very high distance accuracy with a standard deviation of < 0,05m within a angle of 17° at a distance range up to 100m. A medium accuracy of < 0,10 m is reached within 60° angle and a distance range of up to 50m. The beam width of ±2°offers a very focused beam. Both detection areas (17° and 60°) are detected simultaneously in a 66ms cycle, so that the area is scanned 15 times per second. This is the key base for ETF to using the iDRR for vehicle collision protection; an application where valid and reliable real time ability is demanded. Furthermore the sensor possesses an unique feature with its two-dimensional surface detection. By the movement of trucks a third dimension can be computed leading into a 3D model, which can be coupled with material data to serve for safety management.

iDRR transmits the detected information compressed over a robust CAN bus to the indurad radar processing unit™ (iRPU)

ETF is the only OEM using this Safety feature

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Environmental impacts

- 56 % lower NOx + HC emissions
- 63 % lower PM
- 15 -25 % lower CO_2 emissions
  - due to lower fuel consumption
- 85 % waste oils reduction
  - special filter systems; far fewer oil changes necessary
- 47 % lower tire waste
- Considerable reductions in raw material use
  - fuel, oil and rubber

ETF TIER 3 vs. existing trucks, emission reductions in %

Emissions (g/kWh)	Existing trucks Tier 1	ETF Tier 3	Savings with ETF g/kWh	Savings with ETF %
NOx + HC	9.20	4.00	5.20	56.5 %
PM	0.54	0.20	0.34	63.0 %

Emissions (g/kWh)	Existing trucks Tier 2	ETF Tier 3	Savings with ETF g/kWh	Savings with ETF %
NOx + HC	6.40	4.00	2.40	37.5 %
PM	0.20	0.20	0.00	0.0 %

ETF TIER 4i vs. existing trucks, emission reductions in %

Emissions (g/kWh)	Existing trucks Tier 1	ETF Tier 4i	Savings with ETF g/kWh	Savings with ETF %
NOx + HC	9.20	2.00	7.20	78.3 %
PM	0.54	0.03	0.52	95.4 %

Emissions (g/kWh)	Existing trucks Tier 2	ETF Tier 4i	Savings with ETF g/kWh	Savings with ETF %
NOx + HC	6.40	2.00	4.40	68.8 %
PM	0.20	0.03	0.18	87.5 %

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Life-Cycle M & R system with fast major component exchange

- **Integrated Predictive Maintenance Program**
  In combination with ETF's Truck Repair Monitoring System (TRMS)
- **M & R work is completed in the workshop without the truck!**
  Components are exchanged and truck returns to production within 15-45 min
- **Components are tested before re-use!**
  Repair mistakes corrected without extra truck downtime

Wheels, Engines & Cabin: 15 minutes
Axles: 45 minutes

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F-1 pit stop approach:

1. **Message displayed in case of fault**
   for Operator & Workshop (in the Local language)

2. **Operator returns to workshop**
   truck can always return to workshop; No tow truck needed!

3. **Informed workshop is ready with new component**

4. **Truck arrives in workshop and component is exchanged**

5. **Truck back in production between 15 and 45 minutes!**
   Minimal Loss of Revenue

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ir Monitoring System (TRMS)

Due to inherent unreliability exhibited when relying on manual recording of component exchange history, ETF developed an innovative Truck Repair Monitoring System (TRMS).

Critical to efficient operation, all important parts are clearly identified with an unique, permanent barcode. When technicians starts the process of exchanging a major component, they first scan their own barcode which records their name, date and start time; then the barcode of the truck and the barcode of the major component they will be working.

After the work is completed the barcode of the newly installed component is scanned and again the barcode from the truck on which it was installed. The computer system automatically records all the information including the repair times, relevant component identification together with the 'operating hours to failure' of the component. The same procedure will be followed by the next technician who carries out the repair of the faulty component. Again the computer system automatically correlates all relevant information and time line.

Parts usage is integrated in the parts inventory system, automatically generating parts requisitions and delivery from ETF central stockholding.

Global monitoring of all repairs and component exchanges carried out in all our workshops worldwide is linked on-line with ETF Head Quarters. Tracking trends in operational behaviour of in-service components can then be accurately monitored and immediate action addressed if necessary.

Fast and efficient parts exchange is the foundation of ETF high machine availability, providing sustainable world-class performance from its products worldwide.

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ETF Rental Organization

ETF's German Head Quarters are on-line connected with all Rental Projects world-wide

- Global monitoring of all repairs and components exchanges
- Trends in operational behavior of components are accurately monitored and immediate action addressed if necessary
- Automatically generating parts requisitions and delivery from ETF central stockholding

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Workshop & Team

- **Dedicated Workshop, Repairs inside!**
  - Dust-free working conditions at comfortable temperature guarantees best possible quality and shortest repair time
- **Dedicated Team trained for the Trucks and the System**
  - Right mind-set
  - Trained for Truck Repair Monitoring System (TRMS)
- **Special Tooling and Major Components on-site:**
  - Power Pack units, complete Axles, Tires, Cabin, Body, Tipper cylinders, Steering cylinders, Hydraulic pumps & motors etc.
- **On-site Activities:**
  - All repairs and overhauls (mechanical, hydraulic & electronic) enabled by unique testing facility for engines and axles
  - Fabrication of hydraulic hoses
  - Tire repairs
  - Body repairs

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Workshop design

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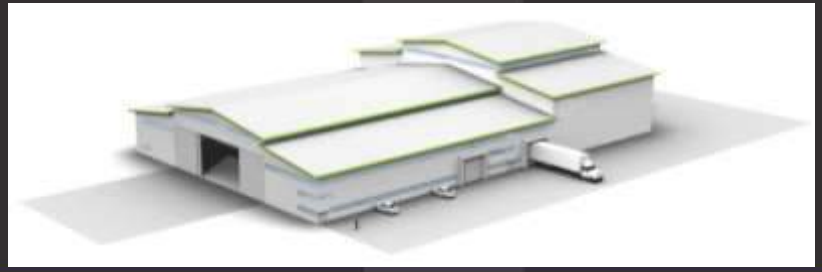
Workshop heating, lighting and ventilation costs are kept to a minimum by incorporating best practices in energy conservation.



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Workshop Layout

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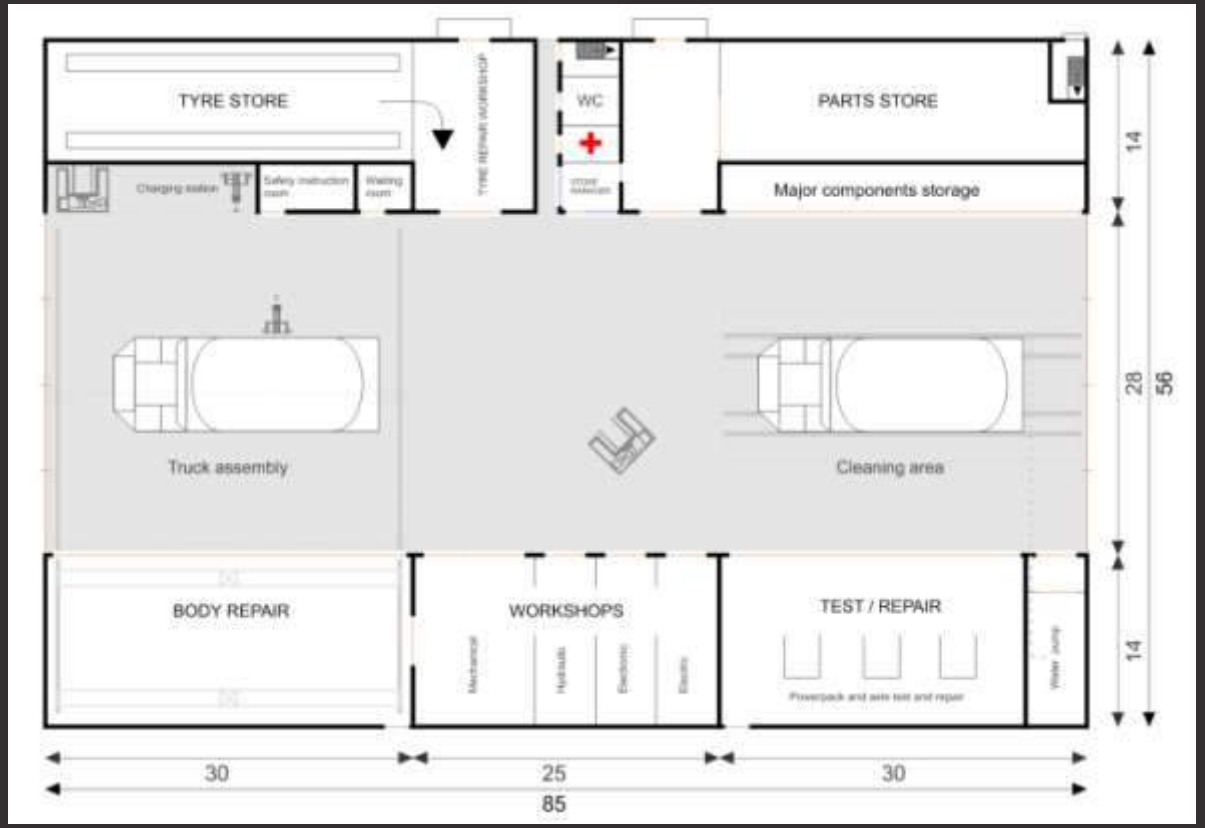

All Maintenance & Repairs inside to assure best possible quality & repair time.

- **Truck entrance from 2 sides**
- **Haul trains can be positioned partly inside and outside the service bay area.**
  (Doors can be closed over link-arm between trucks)
- **Cleaning area with gutters in the floor and roller curtains lowering down from roof**
- **Tyre store and Parts store**
- **Major components storage next to service bays**
- **Test & Repair facilities for Power Packs and Axles**
- **Dedicated work space for:**
  - **Hydraulic components**
  - **Mechanical components**
  - **Electrical components**
  - **Electronic components**
  - **Body repairs (with gantry crane 40t)**
  - **Tyre repairs**
- **Body Repair Space and adjacent service bays will be used during assembly of new trucks**

(All dimensions in meters)

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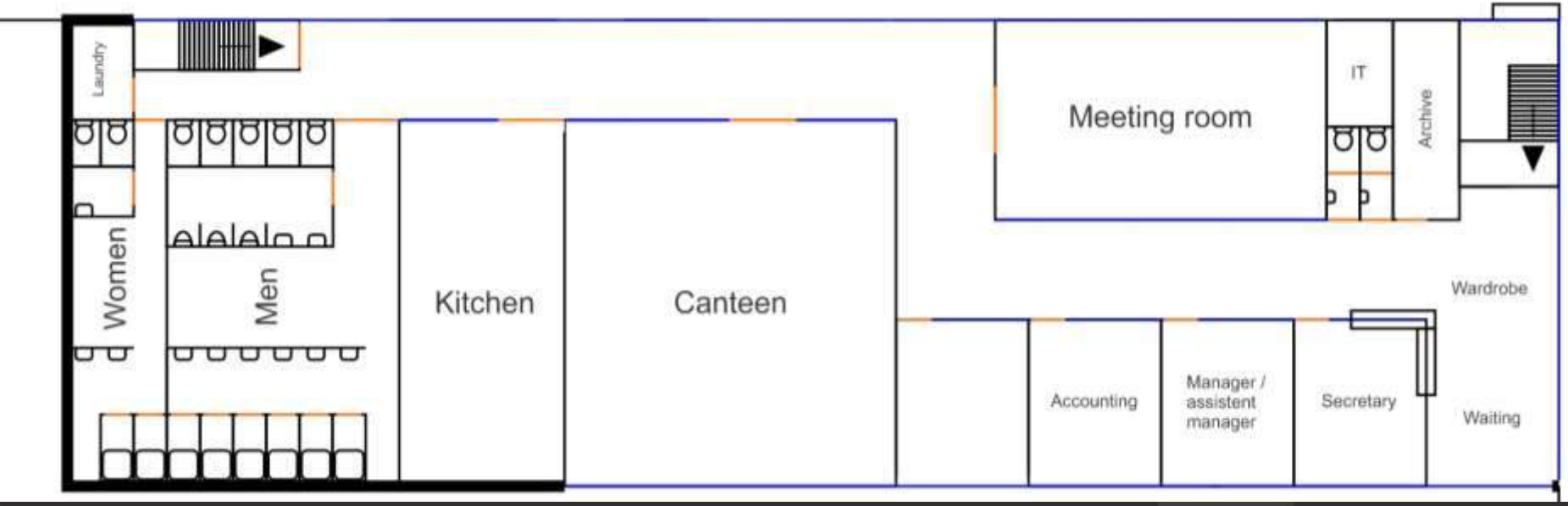
Employee facilities & Office Layout

- Separate entrance for Staff & Visitors



Positioned on 1st floor above Parts Store

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Interchangeable axles for easy maintenance

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Unique testing facility for power packs and axles

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After repairs all components are fully tested before being re-used

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Fast Tire Changes in 15 minutes!

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ETF Mining haulage for the 21st century.

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MT 240 dimensions

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1	Overall width	7600 mm	24 ft 11 in	11	Loading height - empty	5635 mm	18 ft 6 in
2	Overall height	6914 mm	22 ft 8 in	12	Overall height - body raised	16193 mm	53 ft 2 in
3	Overall length	21395 mm	70 ft 2 in	13	Dump clearance	2110 mm	6 ft 11 in
4a	Ground clearance (front)	1380 mm	4 ft 6 in	14	Average body length	12500 mm	41 ft 0 in
4b	Ground clearance	1857 mm	6 ft 1 in	15	Platform height	2550 mm	8 ft 4 in
5	Swingarm ground clearance	406 mm	1 ft 4 in	16	Drivers eyes height	4200 mm	13 ft 9 in
6	Wheel base	12250 mm	40 ft 2 in	17	First axle to front	5595 mm	18 ft 4 in
7	Centerline bogie width	4700 mm	15 ft 5 in	18	Turning radius - between walls	14500 mm	47 ft 7 in
8	Centerline tire width	1600 mm	5 ft 3 in	19	Turning radius inner wheels	3480 mm	11 ft 5 in
9	Width between inner wheels	2700 mm	8 ft 10 in	20	Turning radius outer wheels	11480 mm	37 ft 8 in
10	Body floor height	3300 mm	10 ft 10 in				

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Mining haulage for the 21st century.

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ETF Trucks

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- Highest productivity
- Lowest cost p/ton
- Safest trucks to operate
- Ultimate care for operators & environment
- Designed for +60 till – 50 degrees Celsius
- Innovative mining methods
- Made in Germany, assembled on site

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ETF:
Mining haulage for the 21st century

Made in Germany